Title of the Invention

**MAGNETIC RECORDING MEDIUM AND
MANUFACTURING METHOD THEREOF**

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MAGNETIC RECORDING MEDIUM AND

MANUFACTURING METHOD THEREOF

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to a magnetic
recording medium of an information storage device.
5   More particularly, this invention relates to a magnetic
recording medium suitable for achieving a high
recording density and a manufacturing method of the
magnetic recording medium.

Description of the Related Art

10   As an information-oriented society has made
steady progress, the quantity of information that is
exchanged everyday has kept on increasing. With this
trend, requirements for higher recording density and
greater memory capacity of information storage devices

15   have no limits.

Magnetic recording media that have been put
into practical application at present employ alloys
using Co as the principal component such as Co-Cr-Pt-B
and Co-Cr-Pt-Ta as a magnetic film. The Co alloys

20   assume a hexagonal closed packed structure (hcp
structure) with its easy axis extending in a c-axis
direction. Therefore, crystallographic orientation in
which the c-axis of the Co alloy assumes an in-plane
direction, that is, a (11.0) orientation, is desirable

as a longitudinal magnetic recording medium that executes recording by reversing magnetization inside the plane of the magnetic film. Because the (11.0) orientation is unstable, however, this orientation is

5 not generally achieved even when the Co alloy is directly formed on a substrate.

Therefore, means has been taken that forms a (100)-oriented Cr underlying film before a Co alloy magnetic film is formed, by utilizing the property of

10 the Cr (100) plane assuming a body-centered cubic structure (bcc structure) in that it has high matching with the Co (11.0) plane, and then epitaxially grows a Co alloy magnetic film on the Cr underlying film so that the c-axis of the Co alloy magnetic film faces in

15 the in-plane direction.

To further improve crystal lattice matching in an interface between the Co alloy magnetic film and the Cr underlying film, means that adds a second element to Cr and increases the lattice gap of the Cr

20 underlying film has been employed.

This means can further increase the (11.0) orientation of the Co alloy magnetic film and its coercivity. As examples of such technologies, JP-A-62-257618 (U.S. Patent No. 4,652,499) and JP-A-63-197018

25 both disclose adding V, Ti and the like.

JP-A-11-306532 describes that when a NiTa film or a NiNb film is formed below the underlying film, the (11.0) orientation of the Co alloy magnetic

film can be acquired and high recording density can be
achieved. Further, JP-A-2000-503448 (officially
pronounced unexamined publication) and JP-A-10-143865
describe a method that exposes a first underlying film

5   to a predetermined oxidizing atmosphere and then forms
a second underlying film as means for rendering crystal
grains of a Co alloy magnetic film fine and for
accomplishing the (11.0) orientation.

The factors that are necessary for achieving

10   high recording density are high coercivity and low
noise. A magnetoresitive head having extremely high
reproduction sensitivity and therefore suitable for
high density recording technologies has been mainly
used, but when the magnetoresistive head is used, the

15   sensitivity not only to reproduction signals from the
magnetic recording medium but also to the noise becomes
high. Therefore, the recording medium must have lower
noise than ever.

To reduce the noise of the recording medium,

20   it is known effective to render the crystal grains in
the magnetic film fine and to uniform the crystal grain
diameters. WO98/06093 re-published describes that a
CrTiB alloy is effective for an underlying film for
rendering the crystal grains of the magnetic film fine.

25   Improvement of thermal stability is another
important factor in the magnetic recording medium.
Thermal decay is the phenomenon that a reproduction
output from the magnetic recording medium drops with

the passage of time. Thermal decay develops presumably because magnetization of individual crystal grains becomes thermally unstable as the crystal grains are rendered fine.

5   To solve the problem of this thermal decay, JP-A-2001-148110 proposes a magnetic recording medium that antiferromagnetically couples two magnetic recording layers through a nonmagnetic layer. This coupling is called "AF coupling".

10   To accomplish a magnetic storage device having a recording density of at least 46.5 Mbit/mm^2 (30 Gbit/in^2), it is necessary to accomplish a magnetic recording medium having magnetic characteristics, recording/reproduction characteristics and practically 15 sufficient thermal stability. More concretely, it is necessary to use a magnetic film that has low noise by rendering crystal grains fine, and uses AF coupling to suppress thermal decay. To further improve these characteristics of the medium, it is effective to 20 improve crystallographic orientation inside a plane of a magnetic film formed of a Co base alloy having a hexagonal closed packed structure. When in-plane orientation of the magnetic film can be improved, magnetocrystalline anisotropy becomes strong in the in-25 plane direction, and coercivity of the magnetic characteristics, coercive squareness and remanence magnetization increase with the result of the improvement in recording/reproduction characteristics.

SUMMARY OF THE INVENTION

It is an object of this invention to provide a magnetic recording medium for a magnetic storage device, capable of high-density recording and reproduction of information and having less degradation of reproduction signals due to thermal decay, and a manufacturing method of the magnetic recording medium.

In the invention, the (11.0) crystallographic orientation is improved for a substrate surface of a magnetic film formed of a Co base alloy having a hexagonal closed packed structure. This (11.0) crystallographic orientation preferably has higher (11.0) diffraction intensity by X-ray diffraction so long as the size of the crystal grains remains substantially the same, and can be evaluated as having smaller dispersion of orientation and higher crystallographic orientation when a half value width of a locking curve of a (11.0) diffraction peaks is smaller.

In a magnetic recording medium including a first underlying film formed of a NiTa alloy having a nonmagnetic amorphous structure and deposited on a nonmagnetic substrate such as reinforced glass, and a second underlying film formed of an alloy containing at least Cr and Ti, a first magnetic film formed of a CoCrPt alloy, a nonmagnetic intermediate film formed of Ru and a second magnetic film formed of a CoCrPtB alloy

that are serially formed over the first underlying

film, the object of the invention described above can

be accomplished by a magnetic recording medium wherein

an interface between the first underlying film and the

5   second underlying film is suitably oxidized. The

existence of oxygen can be observed as a peak of an

oxygen component in a depth profile by SIMS secondary

ion mass spectroscopy.

A Pt concentration of the CoCrPt alloy film

10   as the first magnetic film is set to about 8at% or

below so that an anisotropy field Hk of this CoCrPt

alloy film is not greater than 800 kA/m and a recording

head can more easily write information.

The Pt concentration is set to at least about

15   3at% so as to keep lattice matching with the CrTi alloy

as the second underlying film. To improve the (11.0)

crystallographic orientation of the CoCrPtB alloy film

as the second magnetic film, it is necessary to orient

the CrTi alloy film as the second underlying film

20   having the body-centered cubic structure to a (200)

orientation and to epitaxially orient the CoCrPt alloy

film as the first magnetic film having the hexagonal

closed packed structure on the former to the (11.0)

crystallographic orientation.

25   A Ru film is formed as the nonmagnetic

intermediate film between the first and second magnetic

films. This Ru film has the hexagonal closed packed

structure in the same way as the first and second

magnetic films, and its film thickness is about 0.5 nm.
Because Ru is formed to only several atomic layers, it
hardly affects crystallographic orientation.

The closer the length of $\sqrt{2} \times a$ of the CrTi
5 alloy film to the length of c of the CoCrPt alloy film,
the more smoothly the first second magnetic film can be
formed on the second underlying film without
distortion. Consequently, the (11.0) crystallographic
orientation of the first and second magnetic films can
10 be improved. When the Ti concentration of the CrTi
alloy film as the second underlying film is higher than
about 15at%, the crystallographic orientation gets
deteriorated because the difference of the lattice
constant from that of the CoCrPt alloy film as the
15 second magnetic film becomes greater.

When the Ti concentration of the CrTi alloy
film is smaller than about 10at%, on the other hand,
the crystal grains of the first and second magnetic
films deposited over the CrTi alloy film become
20 greater, too, so that the medium noise undesirably
increases.

As the film thickness of the underlying film
becomes smaller, the crystal grains become smaller, and
the medium noise can be reduced during recording and
25 reproduction. When the underlying film becomes thin,
however, the (11.0) crystallographic orientation of the
magnetic film is generally likely to get deteriorated.
In this case, coercivity and remanence magnetization

become smaller and the reproduction output drops.

According to embodiments of the invention, a half value

width of a locking curve of a (11.0) diffraction peak

can keep at least about 8° even when the film thickness

5 of the second underlying film is within a small range

of 5 nm to 15 nm. Since the medium noise can be

reduced without lowering the reproduction output, S/N

can be improved. This (11.0) diffraction peak is

observed as a single peak because the peak by the first

10 magnetic film overlaps with that of the second magnetic

film.

To appropriately oxide the interface between

the first and second underlying films in the magnetic

recording medium according to the invention, the first

15 underlying film is formed and then its surface is

exposed to a trace amount of an oxygen gas so that a

product $(PO_2 \cdot t)$ of an oxygen partial pressure and the

exposure time to the atmosphere is 15 (mPa·sec) to 35

(mPa·sec) when the second underlying film is formed of

20 CrTi, and 20 (mPa·sec) to 40 (mPa·sec) when it is

formed of CrTiB, before the second underlying film is

formed.

Carbon is further formed as a protective film

of the second magnetic film to a thickness of 3 nm to 5

25 nm on the second magnetic film, and a lubricant layer

of adsorptive perfluoroalkeylpolyether is disposed on a

thickness of 1 nm to 2 nm. There is thus obtained a

magnetic recording medium having high reliability and

capable of high-density recording.

When a hydrogen-containing carbon film, a film formed of a carbide such as silicon carbide or tungsten carbide, or a mixed film of these compounds with carbon is used as the protective film, slide resistance and corrosion resistance can be improved advantageously.

When a reproduction portion of a magnetic head is constituted by a magnetoresistive head in a magnetic disk apparatus including the magnetic recording medium described above, a driving portion for driving the magnetic recording medium in a recording direction, the magnetic head having a recording portion and a reproduction portion, means for relatively moving the magnetic head to the magnetic recording medium and recording/reproduction signal processing means for executing signal input to the magnetic head and reproducing output signals from the magnetic head, a magnetic disk apparatus can be accomplished that can acquire sufficient signal intensity in high-density recording and has recording density of at least 46.5 $Mbit/mm^2$.

Other objects, features and advantages of the invention will become apparent from the following description of the embodiments of the invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a model view showing an example of a sectional structure of a magnetic recording medium according to the present invention;

Fig. 2 is a model view showing an example of

5 a film formation apparatus for the magnetic recording medium;

Fig. 3 is a graph showing crystallographic orientation of a magnetic film in the magnetic recording medium according to the invention;

10 Fig. 4 shows an X-ray diffraction pattern of an example of the magnetic recording medium according to the invention and that of a comparative medium;

Fig. 5 is a graph showing a signal-to-noise ratio (S/N) in the magnetic recording medium according

15 to the invention; and

Fig. 6 is a table useful for explaining magnetic characteristics and recording/reproduction performance of an example of the invention and those of Comparative Examples.

20 DESCRIPTION OF THE EMBODIMENTS

[Example 1]

Fig. 1 shows a film structure of a magnetic recording medium according to an embodiment of the present invention.

25 A substrate 10 uses 2.5-inch type aluminosilicate that is chemically reinforced. Over this substrate 10, the following films are formed

serially thereon: first underlying films 11 and 11'

formed of a 62at%Ni - 38at%Ta alloy to a thickness of

30 nm; second underlying films 12 and 12' formed of an

85at%Cr - 15at%Ti alloy to a thickness of 5 nm; first

5   magnetic films 13 and 13' formed of a 75at% Co -

19at%Cr - 6at%Pt alloy to a thickness of 4 nm;

nonmagnetic intermediate films 14 and 14' formed of Ru

to a thickness of 0.5 nm; second magnetic films 15 and

15' formed of a 60at%Co - 20at%Cr - 14at%Pt - 6at%B

10   alloy to a thickness of 15.5 nm; and carbon protective

films 16 and 16' to a thickness of 3.5 nm.

A sheet type sputtering apparatus "mdp250B"

of Intervac Co. is used as a film formation apparatus

and a film is formed at tact of 6.8 sec. An argon (Ar)

15   pressure used for forming each film is 0.8 Pa in all

cases. An oxygen partial pressure of a main chamber 30

(see Fig. 2) is about 7×10^{-7} (Pa) during film formation.

Fig. 2 shows a chamber construction of this sputtering

apparatus. Incidentally, a substrate 20 is set into a

20   feed chamber 21 and is withdrawn from a withdrawal

chamber 29 after predetermined film formation is

completed.

The first underlying film is formed in a

first underlying film formation chamber 22 while the

25   substrate is not heated. The first underlying film is

heated to about 250°C by a lamp heater inside a

heat/oxidation chamber 23 and is exposed to an

atmosphere of a 99%Ar - 1%O_2 mixed gas at a pressure of

0.6 Pa for 4 seconds. The other films are serially
formed thereafter over the first underlying film in a
second underlying film formation chamber 24, a first
magnetic film formation chamber 25, a nonmagnetic
intermediate film formation chamber 26, a second
magnetic film formation chamber 27 and a protective
film formation chamber 28. In this instance, $PO_2 \cdot t$
corresponds to 0.6 Pa x 0.01 x 4 sec = 24 (mPa·sec).
After the films are formed till the carbon protective
film, a film of a composition prepared by diluting a
perfluoroalkylpolyether type material with fluorocarbon
is applied as a lubricant layer to a thickness of 1.8
nm.

[Example 2]

A second magnetic recording medium is
manufactured to substantially the same film structure
and by substantially the same manufacturing method as
those of Example 1. However, the following points are
changed. The second underlying films 13 and 13' are
formed of 82at%Cr - 15at%Ti - 3at%B alloy and its
thickness is changed to 10 nm. The pressure of the 99%
Ar - 1%O_2 mixed gas is changed to 0.8 Pa.

In this instance, $PO_2 \cdot t$ corresponds to 32
mPa·sec.

Fig. 3 shows the change of crystallographic
orientation (Co (11.0) integration intensity) of the
first and second magnetic films in the magnetic

recording media manufactured when $PO_2 \cdot t$ is 5 (mPa·sec) to 43 (mPa·sec). Here, the (11.0) crystallographic orientation is measured by an X-ray diffraction method using Cu-Kα rays and is evaluated by integration

5   intensity of the (11.0) diffraction peaks.

The (11.0) diffraction peaks of the first and second magnetic films overlap with each other and are observed as a single peak. As can be seen from Fig. 3, the Co(11.0) integration intensity is high and the

10   (11.0) crystallographic orientation is improved when $PO_2 \cdot t$ is from 15 (mPa·sec) to 35 (mPa·sec) in the case where the second underlying film is formed of CrTi and when $PO_2 \cdot t$ is from 20 (mPa·sec)to 40 (mPa·sec)in the case where the second underlying film is formed of

15   CrTiB. When dispersion of crystallographic orientation is evaluated by a half value width of a locking curve, the medium of Example 1 has a value of 6.8° and the medium of Example 2, 7.8°.

Fig. 4 shows an X-ray diffraction profile

20   when the medium of Example 1 is measured by X-ray diffraction. The diffraction peak corresponding to the magnetic film is only (11.0) within the range of $PO_2 \cdot t$ where Co(11.0) is strong, and diffraction peaks of other crystallographic planes are not observed. When

25   the profile in the depth-wise direction from the surface of the medium is evaluated by SIM analysis, the peak of oxygen is observed in the proximity of the interface between the first and second underlying

films.   When the sectional structure is observed

through a transmission electron microscope, however, a

new layer due to this oxygen is not distinctively

observed in the interface between the first and second

5   underlying films.   After all, oxygen is assumed as

locally dispersed.

Fig. 5 shows the evaluation result of S/N in

recording/reproduction performance of the magnetic

recording medium shown in Fig. 3.   Here, S/N represents

10   a ratio of an amplitude (peak to peak) of an isolated

read output to a medium noise N at a linear recording

density of flux reversal of 25,000 times/mm in a

magnetic disk apparatus condition of 51 Mbits (at

linear recording density of 595 kBPI, track density of

15   55 kTPI)/mm^2 as a plane recording density.

In the media of Examples 1 and 2 shown in

Fig. 3, S/N becomes high within the range of $PO_2 \cdot t$ where

the Co(11.0) integration intensity becomes high, and

the medium of Example 1 satisfies the apparatus

20   specification of the plane recording density of 48

Mbits/mm^2.   Further, the medium of Example 2 satisfies

the apparatus specification of the plane recording

density of 51 Mbits/mm^2.

Fig. 6 shows recording characteristics and

25   recording/reproduction characteristics of the Examples

of the invention and those of Comparative Examples on

which manufacturing conditions are imposed.

[Comparative Example 1]

A magnetic recording medium of Comparative Example 1 is manufactured to the same film structure by the same manufacturing method as those in Example 1

5   with the exception that the 99%Ar - 1%O_2 mixed gas is not supplied to the heat/oxidation chamber 23 in Example 1.

[Comparative Example 2]

A magnetic recording medium of Comparative

10   Example 2 is manufactured to the same film structure by the same manufacturing method as those in Example 2 with the exception that the 99%Ar - 1%O_2 mixed gas is not supplied to the heat/oxidation chamber 23 in Example 2.

15   [Comparative Example 3]

A magnetic recording medium of Comparative Example 3 is manufactured to the same film structure by the same manufacturing method as those in Example 2 with the exception that the material of the second

20   underlying films 12, 12' is changed to a 77at%Cr - 20at%Ti - 3at% B alloy in Example 2.

[Example 3]

A magnetic recording medium of Example 3 is manufactured to the same film structure by the same

25   manufacturing method as those in Example 2 with the

exception that the thickness of the second underlying

films 13, 13' is changed to 15 nm and the thickness of

the second magnetic films 15 and 15' is changed to 17

nm in Example 2.

5   In the media of all of Examples, the first

magnetic film and the second magnetic film are

antiferromagnetically bonded through the nonmagnetic

intermediate layer, and this AF bonding is confirmed by

the step in the first quadrant of the hysteresis curve

10 by VSM (vibrating sample magnetometer). The field

intensity at which the step develops is 40 kA/m to 70

kA/m in the media of all Examples, and a relatively

large AF bonding magnetic field acts as the medium.

Referring to Fig. 6, the magnetic

15 characteristics are measured by a remanence

magnetization curve. Mrt represents a magnetic moment

per unit area. Hr represents a residual coercive

force. The recording and reproduction characteristic

is evaluated by a ratio (S/N) of an amplitude S (peak

20 to peak) of an isolated read output to a medium noise N

at a linear recording density of flux reversal (25,000

fr/mm) of 25,000 times/mm in a magnetic disk apparatus

condition of 51 Mbits (at linear recording density of

595 kBPI, track density of 55 kTPI)/mm^2 as a plane

25 recording density and by a ratio (Re) of a read output

at flux reversal of 12,500 fr/mm to an isolated read

output.

The plane recording density of the magnetic

disk apparatus can be improved much more with greater
S/N and greater Re.   When Examples 1 and 2 are compared
with Comparative Examples 1 and 2, performance values
can be all improved as a suitable amount of oxygen is

5   supplied between the first and second underlying films.
Though a suitable amount of oxygen is supplied in
Comparative Example 3, lattice matching with the
75at%Co - 19at%Cr - 6at%Pt alloy as the first magnetic
film gets inferior because the Ti concentration of the

10   second underlying film is as high as 20at%.
Crystallographic orientation of Co (11.0) becomes
inferior, too, and both Mrt and S/N get deteriorated.
A thermal decay is evaluated for the medium of Example
3, and degradation of a bit error is found extremely

15   small and provides an excellent result even when the
medium is left standing at 70°C for 100 hours.

The effects of Examples described above can
also be obtained by using a film formation apparatus in
which the degree of vacuum reached is lower and the

20   oxygen partial pressure is greater than those of the
film formation apparatus used in Examples of the
invention, or a film formation apparatus in which the
formation time from the first underlying film to the
second underlying film is long as in an apparatus

25   capable of simultaneously forming the films on a
plurality of substrates, so long as the condition of
$PO_2 \cdot t$ described above is satisfied.

The magnetic recording medium according to

the present invention can suppress degradation of a

reproduction signal resulting from thermal decay and

has a higher S/N than the prior art media. When the

magnetic recording medium according to the invention is

5 used in combination with a magnetoresistive head, a

magnetic storage device having a recording density of

46.5 Mbits/mm^2 (30 Gbits/in^2) or more can be achieved.

Having described a preferred embodiment of

the invention with reference to the accompanying

10 drawings, it is to be understood that the invention is

not limited to the embodiment and that various changes

and modifications could be made therein by one skilled

in the art without departing from the spirit or scope

of the invention as defined in the appended claims.